# THE WEATHER AND CIRCULATION OF FEBRUARY 1961[1]

## An Example of Attentuation in the Long-Wave Pattern

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## 1. CONTRASTING REGIMES IN WINTER 1960–61

Attenuation of the long-wave features in the western portion of the Northern Hemisphere in February 1961 was in marked contrast to the patterns that had prevailed in the preceding winter months. In December [1] and January [2] pronounced amplification of the monthly mean 700-mb. flow pattern dominated the circulation and effectively controlled the weather in North America. Widespread cold conditions in December were repeated in January in the East and South in response to the strong ridge in western North America that extended from the Great Basin to the Arctic Ocean. Substantial changes in the circulation in February 1961 (fig. 1) produced strong damping of the long waves in the mid-troposphere. As a result the country was subjected to mild Pacific air masses instead of cold continental air; the westerlies at mid-latitudes over North America were strengthened; and temperatures in the East became warmer than normal near the end of the winter season.

## 2. SOME ASPECTS OF THE MONTHLY MEAN CIRCULATION

The changes in circulation from January to February are best examined by referring to figure 2, the difference in 700-mb. height departure from normal between the two months. The greatest changes were in the Pacific, where most of the area underwent height rises in February, and the deep, cyclonic center of January at middle latitudes weakened and moved northward. Consequently, the ridge in western North America could no longer be sustained in such strength as was noted in December and January. Heights fell throughout the area from January to February, with maximum change of −420 feet in the Yukon (fig. 2).

The trough in eastern North America advanced to the central Atlantic as flattening of the pattern progressed downstream. Height anomalies increased over most of eastern North America (maximum of +310 ft. in New York) where contour curvature changed from strongly cyclonic in January to slightly cyclonic in February. The result of these changes in and near North America was a decided increase in the average speed of the westerlies at mid-latitudes. The hemispheric zonal index (5° W.–175° E.) was 2 m.p.s. greater in February than it was in January. This increase occurred despite a regional decrease in westerlies from the central Atlantic to Europe where the meridional component of the flow dominated.

In western Europe changes in the average circulation at 700 mb. were large. Diffluent, cyclonic flow in January was replaced in February by a strong ridge (fig. 1) in which there were maximum height rises of 390 feet in Spain (fig. 2). The evolution of this ridge was simultaneous with damping of the pattern in the eastern Pacific and western North America; its growth deserves further comment, based on 5-day mean 700-mb. charts one week apart (not shown).

On the 5-day mean chart for February 2–6, a high center was located just to the west of Morocco with a flat ridge extending northward to Scotland. One week later the High was centered over Gibraltar and the ridge was still rather flat to the north, but the trough southward from Greenland had become quite deep near 40° N. Meanwhile a positive height anomaly center of 390 feet had moved from Gibraltar to northern Spain and increased to 590 feet.

During the week of February 16–20 the anomaly center reached a maximum of 760 feet above normal in France and was associated with a dominant blocking High. In the last week of February the High was observed over the Baltic Sea, still strong, with an omega-configuration well defined by a strong trough (negatively tilted) in the eastern Atlantic and a deep resonant trough from northwestern Siberia to the Red Sea.

Another blocking High was observed on the 30-day mean chart (fig. 1) over northeastern Siberia, but this was considerably weaker than the one in Europe. Its development occurred as the trough along the Asian coast deepened at middle and low latitudes and as the ridge which was in the Arctic Ocean in January retrograded.

[1] The weather of March, April, and May 1961 will be described in the June, July, and August 1961 issues of the Review, respectively.

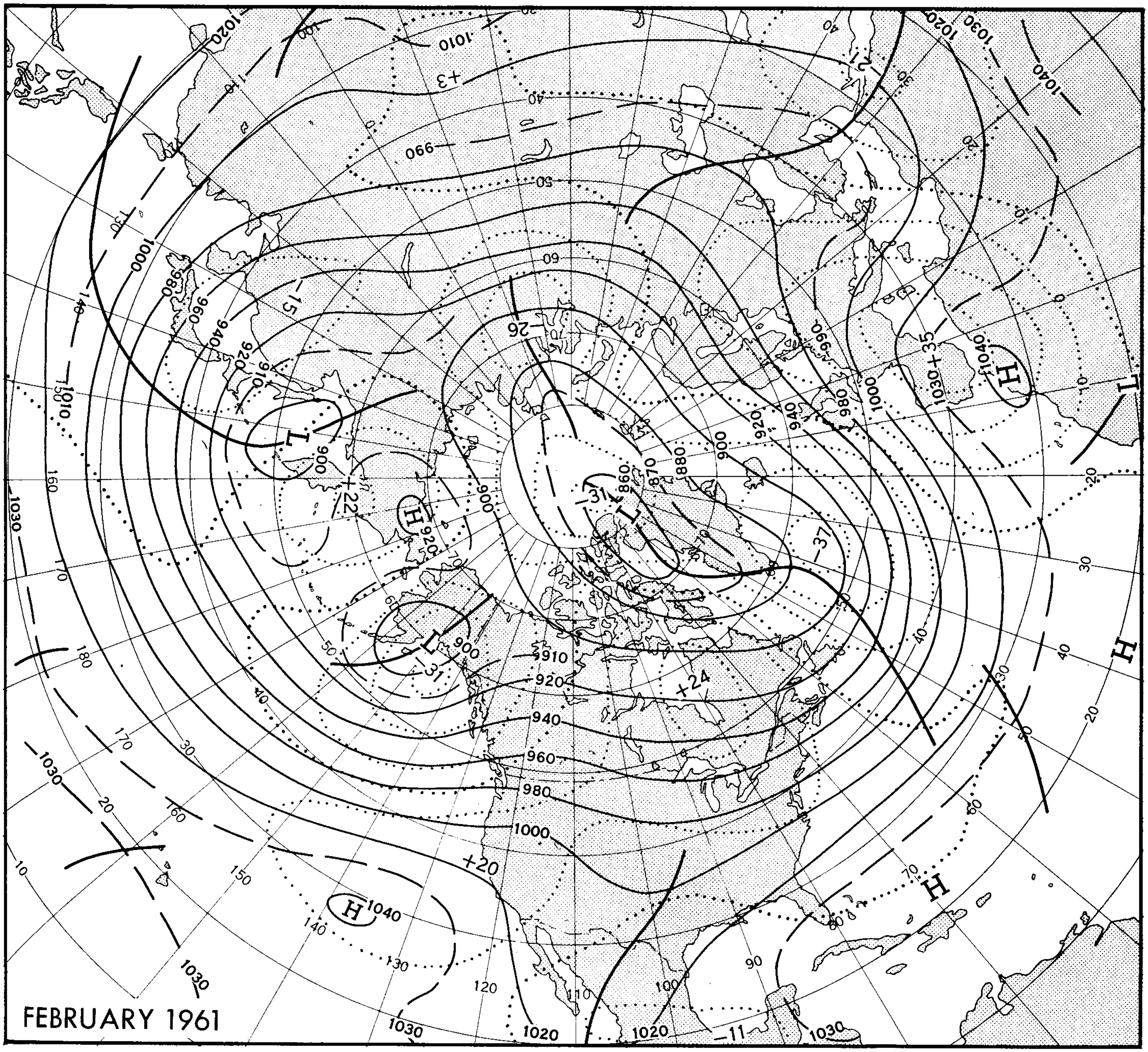



FIGURE 1.—Mean 700-mb. contours (solid) and departures from normal (dotted), both in tens of feet, for February 1961. The trough in the Southwest intensified as the wavelength and westerlies increased at mid-latitudes.

Ordinarily the effect of blocking shows up in a migration southward of the westerlies and a decrease in the average zonal wind speed. But the blocking Highs this month were too far removed to have an appreciable effect on the zonal index in the western portion of the Northern Hemisphere or on the weather and circulation in North America. Dominant in the weather of the United States were the generally westerly flow from the eastern Pacific to the western Atlantic, and especially, the position of the Aleutian Low at an extreme northeast location.

## 3. WEATHER RELATED TO THE MEAN CIRCULATION

### TEMPERATURE

Departures of average surface temperature from normal (fig. 3) were predominantly positive except for a small area in the Southwest where it was 1°–2° F. cooler than normal. The correspondence was close between the flow pattern and the temperature anomaly. Compare the height departure from normal (dotted lines fig. 1) with the temperature departures in figure 3. Considering

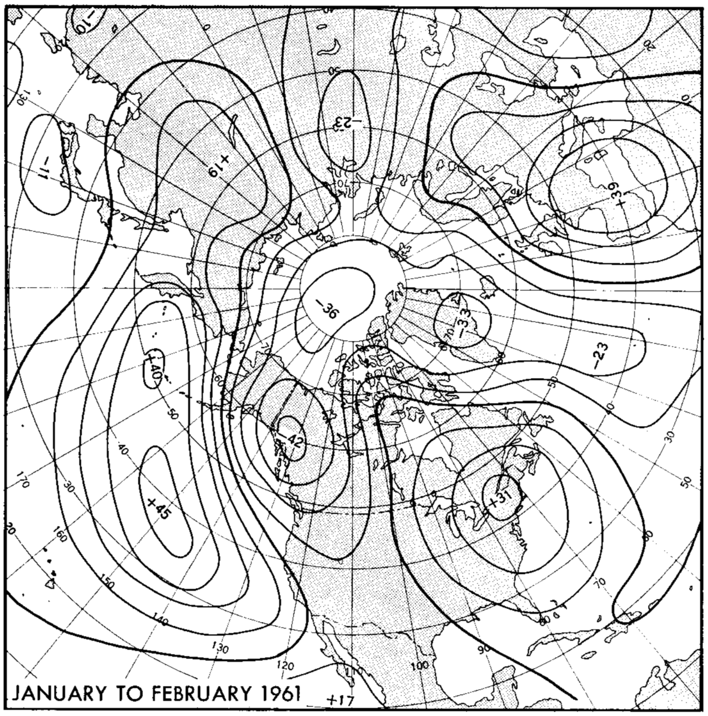



FIGURE 2.—Change of mean 700-mb. height departures from normal (tens of feet) from January 1961 to February 1961. Attenuation of flow pattern near North America in February is accented by falls in the ridge in western North America and rises in the troughs in the eastern Pacific and western Atlantic.

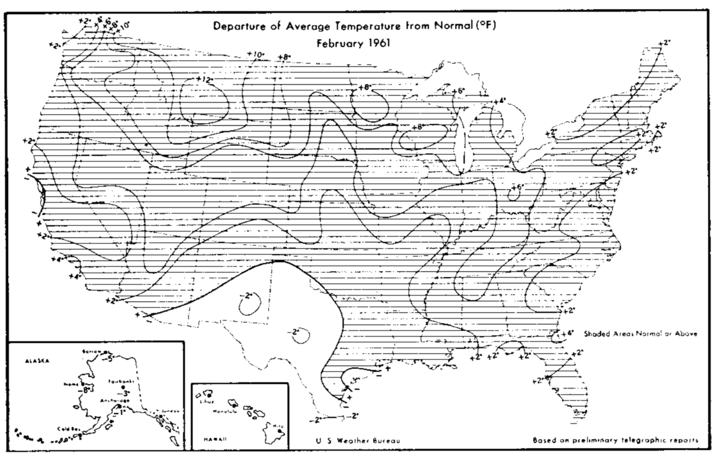



FIGURE 3.—Departure of average temperature from normal (°F.) for February 1961. Height anomaly (fig. 1) and temperature anomaly are almost identical in pattern. (From [5].)

sign only, the similarity in the patterns is remarkable; considering magnitude, the analogy is weaker.

The correlation between local 700-mb. heights and surface temperature anomaly is generally positive, but average correlations in the winter months explain only about 35 percent of the temperature variance [3]. By statistically integrating the behavior of the atmosphere at various distances from the local area, the explained variance can be considerably increased [4]. The synoptic

TABLE 1.—*Class changes of monthly average surface temperature anomalies in 100 cities from January to February 1961*

| Class change* | Frequency (percent) |
|---|---|
| +4 | 0 |
| +3 | 21 |
| +2 | 23 |
| +1 | 30 |
| 0 | 19 |
| −1 | 7 |
| −2 | 0 |
| −3 | 0 |
| −4 | 0 |

*+indicates a change toward higher average temperature. Classes are much below normal, below normal, near normal, above normal, and much above normal.

interpretation of this statistical result is dependent on the well-known fact that the position of the Aleutian Low has a controlling effect on temperatures in much of North America. In February it is normally located over Kamchatka. When it is displaced far to the east (as it was in February 1961), 700-mb. heights are usually lower than normal in northwestern North America (as they were this month)(fig. 1). The resulting westerly flow prevents outbreaks of Arctic air from penetrating into latitudes below 40° or 50° N. Furthermore, increased westerlies at these latitudes in the eastern Pacific (4–8 m.p.s. stronger than normal this February) undergo strong katabatic warming after striking the middle Rockies. The total effect is frequently unseasonable warmth east of the Divide at middle latitudes.

The change in temperature regime from January to February was determined by the circulation change (fig. 2). Consequently, persistence of temperature was large west of the Mississippi River, where height changes were small; to the east, temperatures changed radically where height changes were relatively large. A summary of the January to February changes in monthly average temperature (in terms of five classes) at 100 cities (table 1) indicates the following: (a) 74 percent of the temperatures became warmer, (b) 7 percent became cooler, and (c) 21 percent became warmer by three classes (from much below normal to above normal).

## PRECIPITATION

Precipitation in February (fig. 4) was much more extensive and generally heavier (in 64 of 100 cities) than it was in January [5]. From the Ohio Valley to the western Plateau and from the Canadian border to the Southern Plains, little or no precipitation fell in January, when northerly flow at 700 mb. and sea level inhibited the transport of moist air masses into the country. In February the average flow aloft (fig. 1) and at sea level [6] encouraged the advection of moisture northward from the Gulf of Mexico and eastward from the Pacific.

In the Pacific Northwest there was a deep onshore flow from sea level to 700 mb. This current, the core of maximum wind speed or "jet stream" at 700 mb., supported a very high frequency of frontal systems, 8 to 12 crossing the coast in February. As much as 20 in. of rain fell along the Washington coast as moist, Pacific air was forced to ascend the mountain slopes. Precipitation records for February were broken at Olympia, Wash. (7.02 in. above normal), Sexton Summit, Oreg. (6.75 in. above normal), and several other stations in Washington and Oregon. Flooding was reported in the Puget Sound area, the Olympic Peninsula, and the Willamette Basin.

In the Southeast the distribution of precipitation was related almost ideally to the 700-mb. pattern [7]. Heavy precipitation occurred in the southwesterly flow ahead of the trough and through the weak ridge (fig. 1). There was additional support from the southeasterly anomalous component of the 700-mb. flow and from the warm, moist air at sea level that had a long trajectory from the Tropics. Locally severe flooding from Mississippi to Georgia resulted from 8 in. to more than 17 in. of precipitation that fell in a narrow band from Louisiana to western South Carolina (fig. 4). Several cities in Alabama and Georgia reported the wettest February of record. From early reports precipitation was heaviest in Birmingham and vicinity, where the total was 17.67 in., 12.50 in. greater than normal.

In contrast to the wet weather just described were continued drought conditions over most of the Southwest. Many cities had near-record dryness for February and for the winter season. At Cheyenne, Wyo., and Grand Junction, Colo., February was the 16th and 11th consecutive month, respectively, in which precipitation was less than normal. A deficit of precipitation in February contributed to the driest winter of record at Chicago, Ill., Lansing, Mich., and Burbank, Calif.

## 4. INTRA-MONTHLY TRANSITION

### JANUARY 31–FEBRUARY 14

The 700-mb. circulation in the first half of February (fig. 5A) was transitional between the large-amplitude circulation of January and the higher index state during the last half of February.

In the eastern Pacific, despite appreciable filling, the eastern lobe of the Aleutian Low was still rather strong. The sea level counterpart (fig. 5B) was 11 mb. below normal, as intense as any vortex on the chart, but considerably weaker than the same Low in January, when pressures for the month averaged 20 mb. below normal [2].

The ridge over North America had much less amplitude than in January and was somewhat farther east. Height falls at 700 mb. eroded the western portion of the ridge at middle and high latitudes as the center of positive height departure from normal jumped from British Columbia in January to Hudson Bay in the first half of February.

In the Atlantic the strong trough at 700 mb. progressed from the east coast and deepened as cold air was injected from Canada. The Icelandic Low at sea level was near its normal position, but was 11 mb. deeper than normal.

The distribution of temperature departures from normal

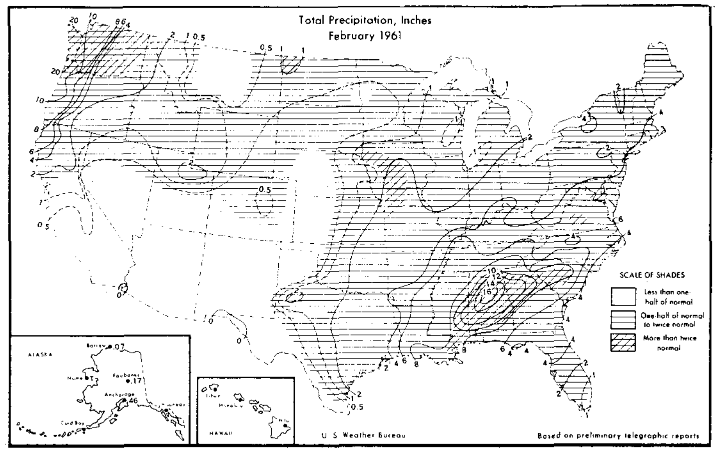



Figure 4.—Total precipitation, inches, for February 1961. Locally severe flooding in the Northwest and in the Southeast was closely related to strong southwesterly flow in advance of mean troughs. (From [5].)

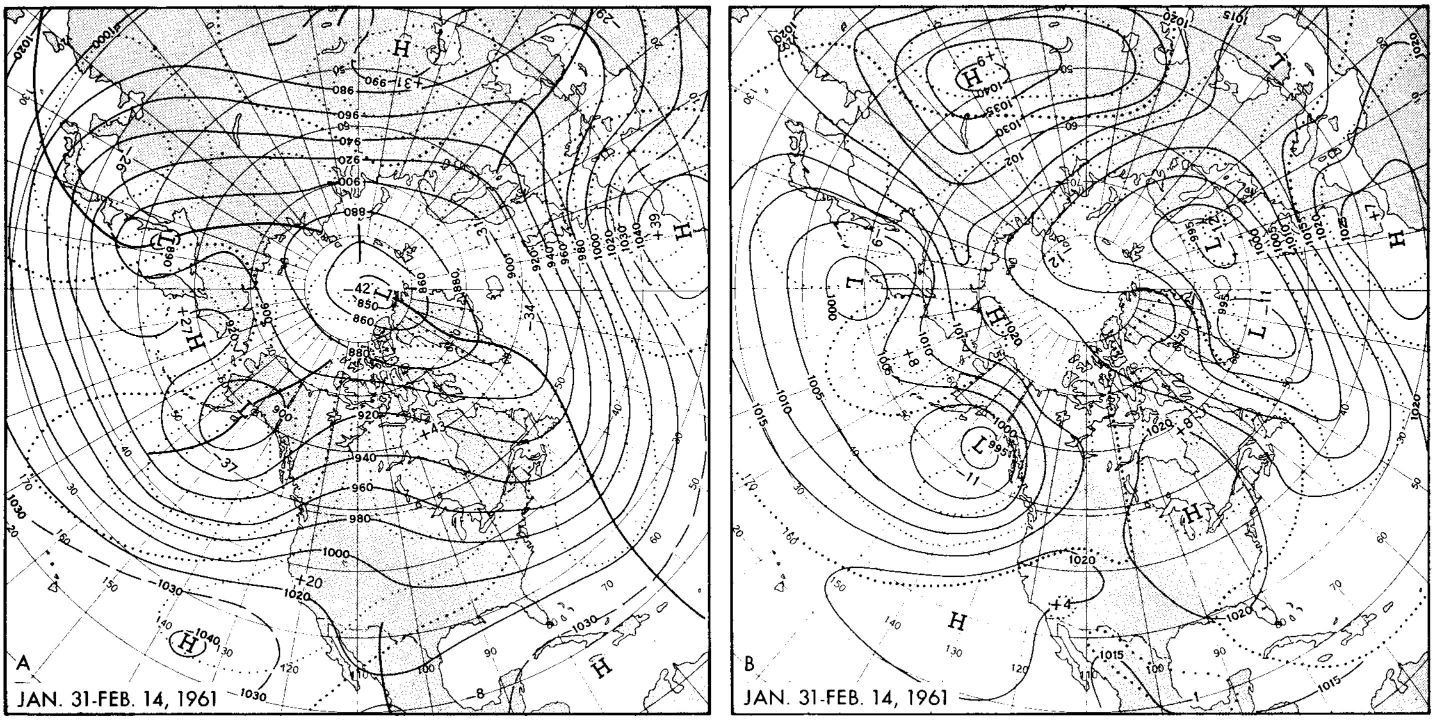
for January 31–February 14 is shown in figure 5C. From the Central Plains westward, temperatures ranged from 4°–18° F. warmer than normal. Most of this warmth was a function of the ridge aloft; some was related to the increasing westerlies and the deep Low in the Gulf of Alaska. In the eastern portions of the country cold air was closely associated with the anomalous northerly components of the flow at 700 mb. and at sea level. The source and trajectory of the cold air observed in the East was implicit in the strong ridge at sea level from Hudson Bay to the Gulf Coast (fig. 5B).

### FEBRUARY 15–MARCH 1

During the last half of February broadscale damping of the major perturbations occurred in mid-latitudes from the central Pacific to the eastern Atlantic (fig. 6A). The Aleutian Low continued to weaken as heights increased as much as 480 feet in the eastern Pacific. At the same time heights decreased over Canada, and cyclonic flow prevailed from Alberta to Labrador, in place of the ridge formerly there. In the western Atlantic height rises were widespread and reached a maximum of 390 feet where there had been a trough the first half of the month. This nearly simultaneous growth of the Bermuda High and the High in the eastern Pacific suggests a teleconnection often noted in a period of rising index.

General height falls in higher latitudes and rises in middle latitudes contributed to a pronounced strengthening of the zonal index in temperate latitudes. At mid-month the 5-day mean 700-mb. zonal index (5° W.–175° E.) was 10.5 m.p.s., only 0.3 m.p.s. above normal. By the end of February, however, the index had jumped to 13.6 m.p.s., 3.8 m.p.s. above normal.

Deepening of the trough in the lee of the Rockies was assisted by the increased westerlies impinging on this natural barrier. Accompanying the increased cyclonic



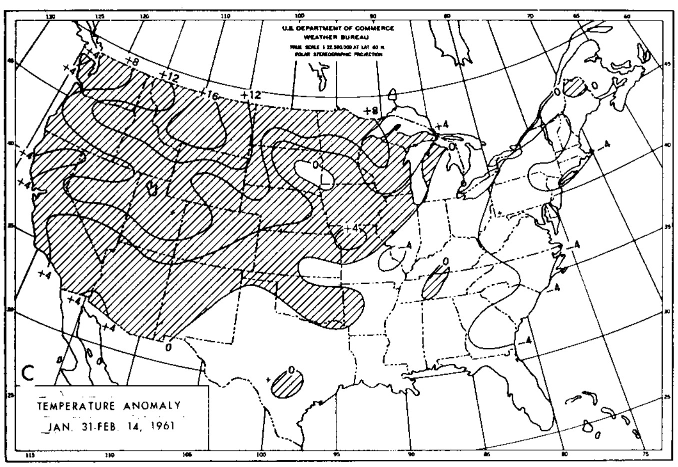



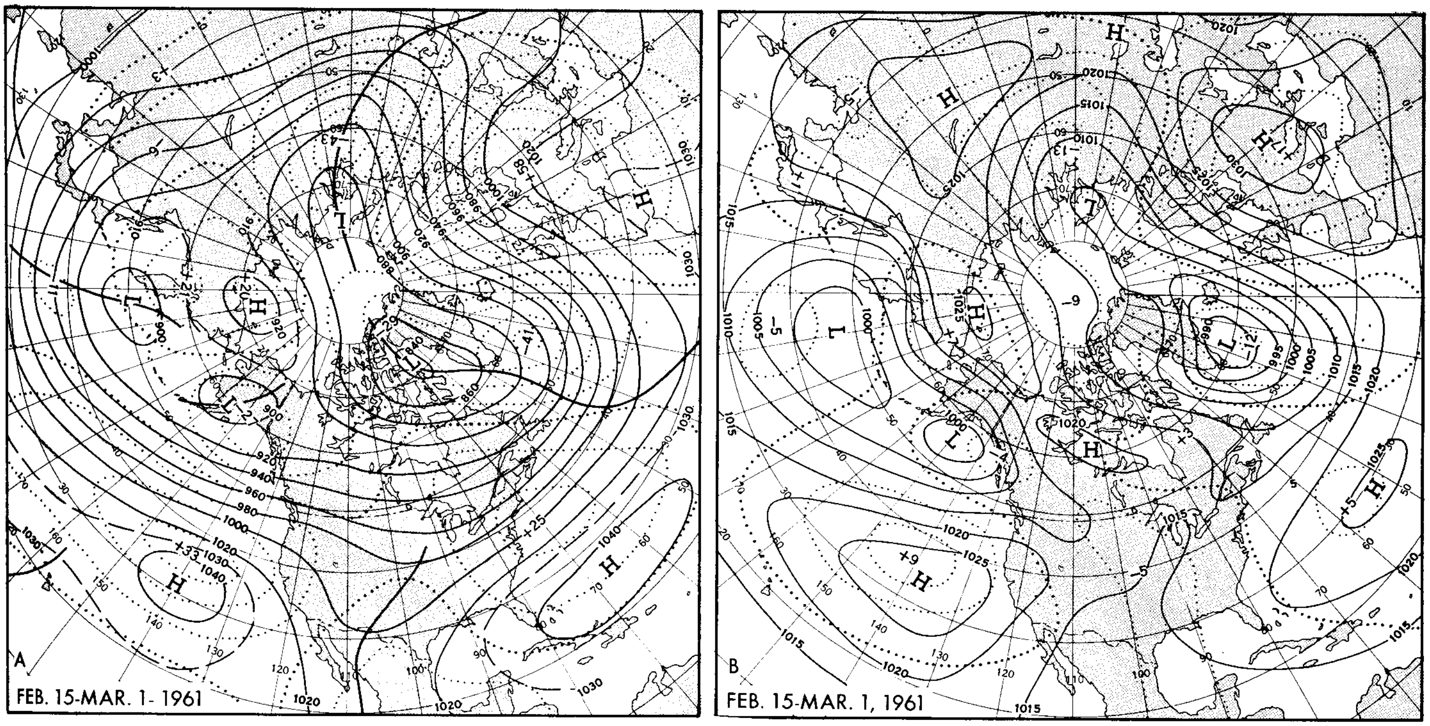

FIGURE 5.—(A) Mean 700-mb. contours (solid) and departures from normal (dotted), both in tens of feet. (B) Mean sea level pressure (solid) and departures from normal (dotted), both in millibars. (C) Departure of average temperature from normal (°F.). All charts for January 31–February 14, 1961.

flow were vigorous frontal systems that crossed the Rockies and intensified just to its lee. In fact, there were 16 days of frontal activity in Montana during the month, a maximum for the country.

The sea level chart for February 15–March 1 (fig. 6B) should be compared with that of the first half of February (fig. 5B). Changes indicated are similar to those found on the 700-mb. charts for the same periods. The complementary anticyclogeneses in the eastern Pacific and the western Atlantic are clearly portrayed by the dotted lines showing the sea level pressure departures from normal. In the same period sea level pressures fell 5–9 mb. from the Gulf of Mexico to Baffin Bay. The direction of the flow and its anomalous components are indicative of the changed regime. Note especially the northerly direction in the West and the southerly direction in the East.

A great warming in the East and a cooling in the West were the principal reactions to the reversed flow. Figure 6C shows that average temperatures for February 15–March 1 were generally 4°–8° F. warmer than normal over most of the country and a few degrees cooler in the Southwest. But the changes from the first half of February to the last half were quite large. In the East, for example, temperature anomalies showed positive changes of 12°–16° F. in a belt from Florida to New York; west of the Plains States negative changes ranged from 4°–10° F.

As the transition in the circulation proceeded, there was a definite change in the tracks of cyclones in and near North America. This might be anticipated from a study of figures 5 and 6, but for additional emphasis and clarity, figure 7 is presented. This figure was prepared by separating the tracks of migratory cyclones published in



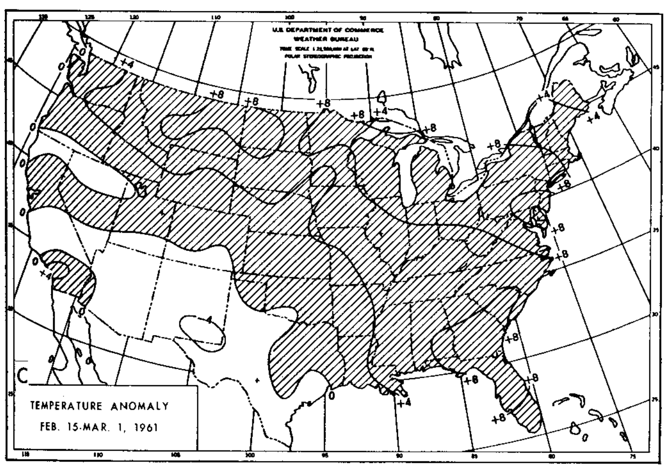




FIGURE 6.—(A) Mean 700-mb. contours (solid) and departures from normal (dotted), both in tens of feet. (B) Mean sea level pressure and departure from normal, both in millibars. (C) Departure of average temperature from normal. All charts for February 15–March 1, 1961.

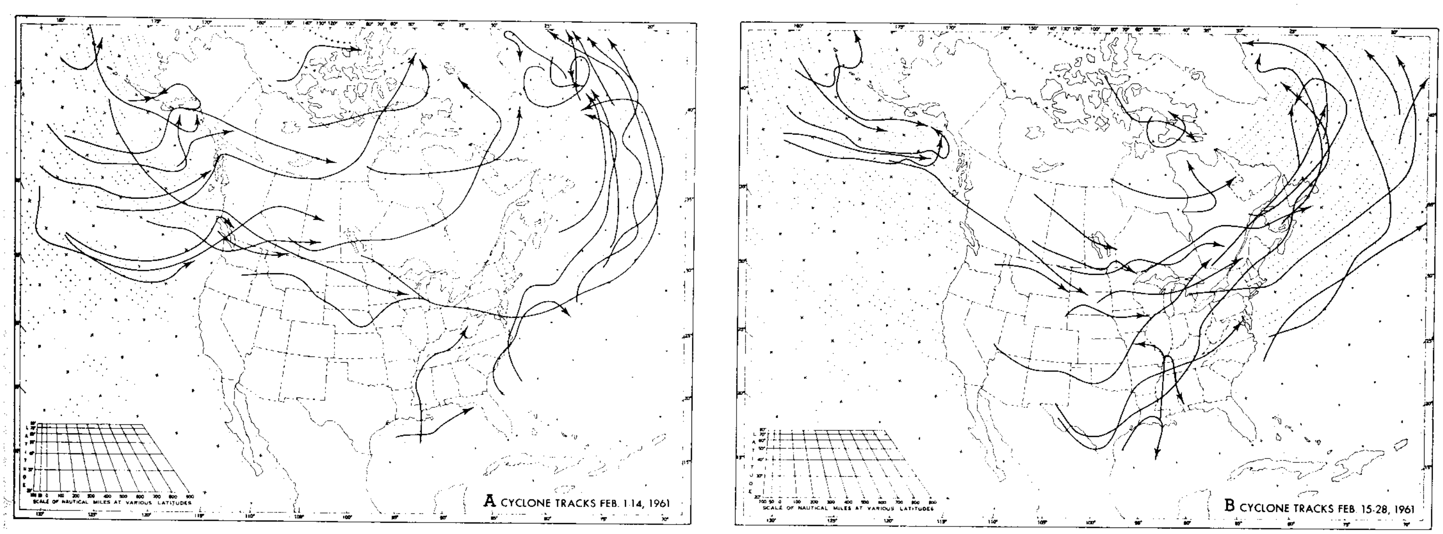



FIGURE 7.—Paths of migratory cyclones (A) Feb. 1–14, 1961, and (B) Feb. 15–28, 1961. Note general shift of cyclones northward in both oceans and increased frequency of tracks originating in the Southwest from the first half to the last half of February.

[6] into halves; those originating in the first half of February (A) and those originating in the second half (B).

These tracks clearly illustrate the changes discussed above. The transfer of cyclonic activity in the Pacific to a more northerly locus was a typical result of anticyclogenesis in the eastern Pacific. In the Atlantic the average storm track was displaced to the north in a similar manner for a similar reason.

Storminess east of the Rockies reached its highest frequency during the last half of February. Essentially, there were two major storm tracks—one along the Canadian border, the other from the Southwest to the Northeast. Both tracks can be reasonably "fitted" to the flow at 700 mb. and to the mean sea level chart. Along the sea level track, associated with the new trough in the Plains, was found the most intense storm of the winter season in the East, as well as those systems responsible for record-breaking precipitation in the Southeast.

REFERENCES

1. R. H. Gelhard, "The Weather and Circulation of December 1960—An Unusually Cold Month in the United States," *Monthly Weather Review*, vol. 89, No. 3, Mar. 1961, pp. 109–114.
2. R. A. Green, "The Weather and Circulation of January 1961," *Monthly Weather Review*, vol. 89, No. 4, Apr. 1961, pp. 137–143.
3. D. E. Martin and W. G. Leight, "Objective Temperature Estimates from Mean Circulation Patterns," *Monthly Weather Review*, vol. 77, No. 10, Oct. 1949, pp. 275–283.
4. W. H. Klein, B. M. Lewis, and I. Enger, "Objective Prediction of Five-Day Mean Temperatures During Winter," *Journal of Meteorology*, vol. 16, No. 6, Dec. 1959, pp. 672–682.
5. U.S. Weather Bureau, *Weekly Weather and Crop Bulletin, National Summary*, vol. XLVIII, Nos. 6 and 10, Feb. 6, and Mar. 6, 1961.
6. U.S. Weather Bureau, *Climatological Data-National Summary*, vol. 12, No. 2, Feb. 1961, Chart IX.
7. W. H. Klein, "Winter Precipitation as Related to the 700-mb. Circulation," *Bulletin of the American Meteorological Society*, vol. 29, No. 9, Part 1, Nov. 1948, pp. 439–453.